

# **Commercial Mobile Radio Services for Public Sector Agencies**

By

Carl Kain

Mitretek Systems, Inc.

Prepared for the USDOT ITS Joint Program Office

October 2003

## ABSTRACT

*There are many actions taken recently by the Federal Communications Commission (FCC) that have a major impact on the use of both commercial services and land mobile radio by public sector agencies. As a result, many of these agencies may have to perform costly upgrades or replacements of their land mobile radio systems, or systems that use commercial technologies such as CDPD. This paper describes the FCC actions, the wireless communications systems that are affected, and examines the potential role of emerging 2.5 and 3G commercial mobile radio systems for public sector agency use.*

## INTRODUCTION

Public sector agencies normally use traditional land mobile radio systems in the frequency bands the Federal Communications Commission allocate for public safety use. Users include police and fire departments, State and local government, highway maintenance, public transit and other public agencies. There are many older analog radio systems still in use and some agencies have leased commercial services, such as Cellular Digital Packet Data (CDPD), for their data applications. Many of these agencies are faced with replacing aging equipment, dealing with several recent regulatory actions by the Federal Communications Commission (FCC), and trying to implement new data services. Replacing an older wideband radio system with a new narrowband system can be an extremely expensive proposition, especially for small and medium sized agencies. Even agencies with new systems might find it difficult to implement some of the more advanced data applications.

Writing surveys of commercial wireless communications is a difficult and risky proposition in the current environment. Since September, 2002, there have been three new data services introduced, announced phase-outs of older data services, numerous service price changes, major changes of availability in the top 75 markets, and several landmark decisions by the FCC that impact both cellular telephony and public safety radio spectrum. Changes in pricing, new products, and introductions of some additional new third generation (3G) services are becoming almost a daily occurrence. This paper, in addition to being a survey of emerging wide area wireless communications, discusses several regulatory issues since they will influence how an agency should upgrade or possibly replace a land mobile communications system. This paper also places an emphasis on the currently available high speed data services in the United States such as 1xRTT and the General Packet Radio Service (GPRS). We have been testing these services and some preliminary data will be presented in this paper.

The scope of this paper is limited to examining commercial mobile radio systems that have the potential to be used as a replacement for a public land mobile radio system. Therefore, for a commercial system to be included, it must offer both a voice service and a data service for use over a wide area to vehicles moving at highway speeds.

## DATA REQUIREMENTS AFFECTING LAND MOBILE RADIO USE

Land mobile radio systems that operate in frequency bands allocated to public safety by the FCC are used primarily for voice dispatch, and some limited data applications usually pertaining to automatic vehicle location (AVL), fleet management and mobile data terminal support. Voice channels in the public safety band are relatively scarce in most parts of the country, and implementing data applications usually requires converting a limited number voice channels for data use to be shared by the entire agency. This type of operation severely limits the agency's ability to download and collect information from vehicles while in service.

Many data applications are not implemented due to the limitations of the agency's radio system. One of the limiting factors in the ability for public safety systems to support data is due to the way the systems are implemented. Most public safety land mobile radio systems are built with a minimum number of base stations, so each base station is covering a significant geographical area. The channels are equal-sized narrowband channels that are optimized for voice. When channels are allocated to data, all units within the coverage area of the base station have to share a limited number of these low capacity channels, so it is easy to overload the channel. In addition, many data applications are asymmetric; they normally need higher capacity on the downlink than the uplink. The public safety channels provide the same capacity in both directions, making implementation of web-based applications difficult. Many public agencies have subscribed to commercial services like Cellular Digital Packet Data (CDPD), but emerging data applications such as biometrics for fingerprint or license identification, high resolution photographs, and limited-motion video have higher bandwidth requirements than CDPD can provide and they either do not work, or work with very long delays.

## REGULATORY ACTIONS AFFECTING USE OF LAND MOBILE RADIO AND COMMERCIAL SERVICES

Public agencies normally use land mobile radio systems in the public safety allocations either in the 800 MHz band, or in frequencies below 512 MegaHertz (MHz). Commercial services commonly used include CDPD, Cellemetry, and dispatch services from Nextel communications. All of these systems are being impacted by FCC regulatory action.

### Regulatory Actions

- *Refarming*
- *The Biennial Review*
- *New Public Safety Spectrum*
- *Improving Public Safety Communications in the 800 MHz band*

### *Refarming*

In 1995, the FCC adopted a Report and Order which created a new narrowband channel plan in the land mobile radio bands below 512 MHz and adopted a transition schedule based on the type acceptance process. In February 1997, the FCC adopted a Second Report and Order which consolidated the 20 radio services into two; public safety and

industrial/business. It also changed the method applicants can use to hire frequency coordinators to obtain frequency assignments.

In a related docket, the 2<sup>nd</sup> Report and Order and Further Notice of Proposed Rulemaking on “Promotion of Spectrum Efficient Technologies on Certain Part 90 Frequencies”, the FCC imposed hard deadlines for replacing wideband (25 kHz channel) equipment operating at frequencies below 512 MHz with 12.5 kHz narrowband equipment. This docket, released February 25, 2003, impacts users of Very High Frequency (VHF) and Ultra High Frequency (UHF) wideband radio equipment for their land mobile radio systems. Beginning 6 months after the Report and Order is published in the Federal Register, new applications for wideband systems and modifications that change the coverage of existing systems will not be accepted. Wideband replacement equipment will no longer be manufactured or imported in 5 years. Public sector agencies using frequencies in the non-public safety pool (e.g. railroad frequencies for commuter trains) will have to convert to 12.5 kHz equipment in 10 years. Public safety band equipment must be replaced in 15 years. This means that public agencies will have to eventually replace every wideband radio in the fleet, and possibly re-engineer part of their networks to maintain coverage with the new narrowband equipment.

#### *The Biennial Review*

The FCC periodically reviews rules and regulations to determine if they are no longer appropriate. The FCC recently deleted requirements for cellular providers to offer analog service after December 31, 2007. CDPD and Cellemetry services are based on analog cellular technology. CDPD is currently in use by many police departments. Users of this service will likely have to choose a replacement within the next two to five years. ATT Wireless has already announced a phase-out schedule for their CDPD service.

#### *New Public Safety Spectrum*

The FCC recently reallocated television channels 63, 64, 68 and 69 (24 MHz of spectrum) for public safety use (700 MHz band). The availability of this spectrum depends on whether there is an active TV station in the desired region. These stations will eventually be required to vacate the band, and are expected to do so within the next 5 years. These actions are linked with the implementation of digital television.

##### Public Safety Channel Bandwidths in 6 MHz Wide TV Channels:

- 12.5 KHz
- 6.25 KHz (future)
- 50 KHz wideband data
- 3 x 50 KHz wideband data
- 37% of spectrum is in reserve

There are several types of channel designations in this allocation including general use channels and interoperability channels. The interoperability channels are used for communications between different agencies, for example, when police, fire, and highway maintenance have to respond to a traffic incident. The recommended standard for use in these “interoperability” channels in this new allocation is a 12.5 kHz bandwidth version of Project 25 (a set of industry standards for mobile radio used primarily by public safety

agencies). The data channels allocated in this service are 50 kHz, with the potential to aggregate up to three channels, creating a 150 kHz wideband channel. This will severely limit the maximum potential data rates compared to new commercial services that use channel bandwidths of 200 kHz to 1.25 MHz (with future plans for 5, 10 and 15 MHz channels).

### *Improving Public Safety Communications in the 800 MHz Band*

The FCC issued a notice of proposed rulemaking that is seeking comment on several issues stemming from an increasing number of interference complaints from users of 800 MHz public safety systems. This band is currently interleaved with public safety users, private radio users, Specialized Mobile Radio (SMR) systems, and Nextel's network. There have been several proposals to restructure the band to minimize or eliminate interference, and offers by Nextel to fund some of the relocation of the public safety radio systems of first responders. The potential impact would be either retuning or replacing radios in 800 MHz systems if they are relocated. Also, the same would be true for agencies leasing Nextel equipment for use in their operations. The Nextel equipment would have to be retuned or replaced.

## **COMMERCIAL SERVICES**

There are several classes of commercial services that can provide voice and data services in a similar manner to land mobile radio. Commercial Mobile Radio Service (CMRS) providers are defined by the FCC as those leasing services with full connection to the public switched telephone network (PSTN).

The terms (SMR) and Enhanced SMR (ESMR) refer to system operators who cater to business and industrial customers, and have systems with either no connection, or limited connection to the public switched telephone company. These companies operate in a different frequency band than the cellular and Personal Communications Systems (PCS) systems. The largest ESMR company, Nextel, has full connection to the PSTN and the operational distinction between Nextel and other CMRS carriers has vanished. There are also private data networks such as RAM and ARDIS. RAM has been purchased by Cingular and is being used as one of their data service modes.

A decision to use a commercial service as a replacement for wideband land mobile radio will depend on many factors. The type and condition of the agency's legacy systems is one factor. If the manufacturer has begun phasing out the product line, the public agency will have to use new narrowband (12.5 kHz) equipment, and will have to replace every base station transmitter and every mobile transceiver. This may result in different coverage patterns and will require the construction of new base stations. For a medium or small agency, this could be prohibitively expensive, and commercial services might be an attractive alternative.

This document does not address the life cycle costs or institutional decision factors that are necessary to make a proper decision. These two topics have been covered extensively

by the Public Safety Wireless Network Program (PSWN), a joint venture of the US Department of the Treasury and the US Department of Justice. The PSWN website, [www.pswn.gov](http://www.pswn.gov) has several excellent reports that can be downloaded for free that cover these topics.

### *A Brief Explanation of 1G, 2G and 3G Commercial Services*

The terminology used by commercial wireless vendors is not only complex, but the terminology has changed several times in the past few years. Carriers may upgrade services several times during the next few years. To accurately assess how these migration paths will influence subscriber plans and decisions, it is crucial that the subscribers understand the options and implications. This is of particular importance to agencies who expect their equipment to remain for many years. Some of the agencies that leased CDPD service were surprised to see the service, barely five years old, being phased out. Some of the emerging technologies are just intermediate steps in a 3G transition plan, and may be around an even shorter period of time. Understanding the transition path and the speed at which some of these technologies may become obsolete will help agencies decide not only what to buy, but how it is implemented.

Table 1 summarizes the data services associated with various cellular technologies. The first generation of cellular radio is the familiar analog cellular service in the 800 MHz band. The FCC licenses two providers in each metropolitan area. The second generation services are the PCS in the 1.9 GHz band and the analog cellular radio services in the 800 MHz band that have been converted to digital. Enhanced packet data services are planned for some of these networks, and these are referred to as the 2.5G systems. 3G systems are third generation wireless communications systems being standardized by the International Telecommunications Union (ITU) as part of the International Mobile Telecommunications for the year 2000 (IMT-2000) effort. The goals of IMT-2000 are to provide voice comparable to the public switched telephone network, and to provide high speed circuit switched and packet switched data services. These systems will provide a minimum data rate of 144 Kbps for users in motor vehicles moving over a large area at highway speeds, a data rate of 384 Kbps for users that are stationary or moving at pedestrian speeds, and a data rate of 2 Mbps for office use.

Communications companies wishing to protect their investment in 2G systems, and desiring a simplified migration path to 3G, have promoted several different radio standards. The two primary international standards being pursued in the US are CDMA2000 (being implemented by companies such as Verizon and Sprint), and GSM/WCDMA (being implemented by carriers such as T-Mobile and ATT Wireless).

<b>Commercial Mobile Data Services</b>	<b>Uplink Max. Rate</b>	<b>Technology</b>	<b>Summary</b>
Mobitex / RAM	8 kbps	Packet switched narrowband 12.5 kHz channel for data only	<ul style="list-style-type: none"> <li>- Supports Internet Protocol</li> <li>- Send/Receive 2-way message</li> <li>- Low data rate</li> </ul>
TDMA / GSM Circuit Switched	9.6 kbps	Using voice channel for data; 2G	<ul style="list-style-type: none"> <li>- Supports Internet Protocol</li> <li>- Easy to implement</li> <li>- Unable to perform simultaneous voice &amp; data</li> </ul>
CDMA Circuit Switched	14.4 kbps		
CDPD	19.2 kbps	Analog channel for multiple access data 1G	<ul style="list-style-type: none"> <li>- Widespread coverage</li> <li>- Supports Internet Protocol</li> <li>- 5-10 kbps typical</li> <li>- Carriers phasing out service</li> </ul>
Packet Stream	19.2 kbps	iDEN	<ul style="list-style-type: none"> <li>- Proprietary technology from Motorola</li> </ul>
GPRS	171 kbps	GSM; 2.5G	<ul style="list-style-type: none"> <li>- Concurrent voice &amp; data</li> <li>- Transmission delay; not suitable for streaming apps.</li> <li>- 20-40 kbps typical on uplink</li> </ul>
1xRTT	114 kbps	CDMA; 2.5G	<ul style="list-style-type: none"> <li>- Concurrent voice &amp; data</li> <li>- 40-60 kbps typical on uplink</li> </ul>
EDGE	384 kbps	GSM; 2.5G	<ul style="list-style-type: none"> <li>- Evolution of GPRS</li> </ul>
1xEVDO	384 kbps	CDMA – Data Only; 3G	<ul style="list-style-type: none"> <li>- Separate CDMA Data Channel</li> </ul>
WCDMA	2.4 Mbps	3G evolution for GSM	<ul style="list-style-type: none"> <li>- May be available in 2004</li> </ul>
CDMA2000	2.4 Mbps	3G evolution for CDMA	<ul style="list-style-type: none"> <li>- May be available in 2003-2004</li> </ul>

**Table 1. Summary of Commercial Data Services***Analog Cellular-Based Services*

Analog cellular service is still the most widely available service in the United States. In addition to voice service, there are three types of data services available; circuit switched cellular, CDPD, and cellemetry. Circuit switched cellular uses a full voice channel for the entire time the connection exists. Due to the harshness of the wireless environment, the user can expect to get approximately 4800 bps user throughput using a standard cellular modem. Using enhanced throughput cellular (ETC), users can expect 9600 bps under most circumstances and 14,400 bps in areas of very good coverage.

CDPD is a protocol for the wireless transmission of data using packets over the analog cellular voice network. This protocol offers multiple access channels between the mobile terminals and the base station with a transmission rate of 19.2 Kbps per channel.

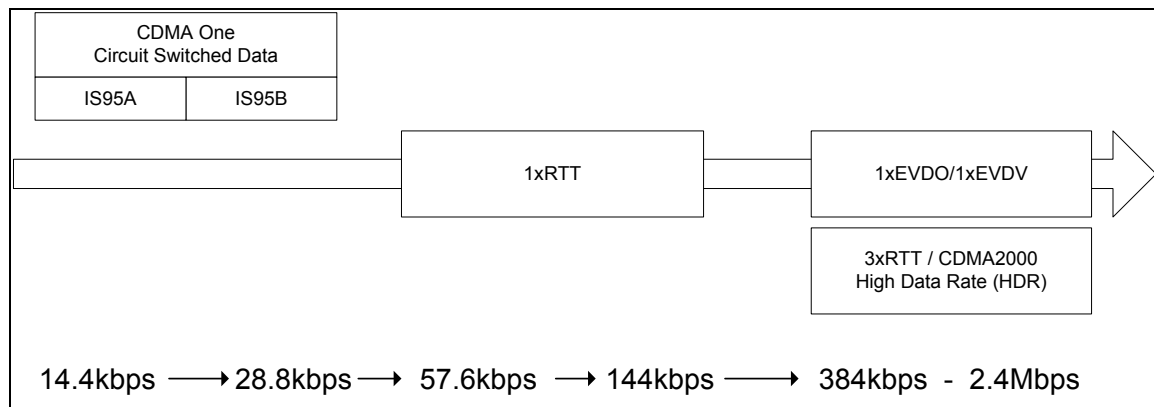
Cellemetry is a very low speed telemetry data service that uses the control channels of the analog cellular telephone system. In Cellemetry, a data terminal sends its mobile identification number, but instead of sending an electronic serial number, it sends a data packet that can contain up to 32 bits. This is sufficient for small information packets such as GPS data for AVL.

### *Code Division Multiple Access (CDMA)-Based Services*

In CDMA, many users access a channel that is 1.25 MHz wide. Instead of each user having their own channel, they are separated by codes, as opposed to being separated in time or frequency. Most providers have implemented 14.4 kbps as the rate used for circuit switched data service, and for their wireless Internet service.

1xRTT is the first high speed packet data service offering from the CDMA-based PCS companies. Packet data is sent on supplemental code channels with maximum theoretical data rates of 144 kbps in the reverse direction (from mobile to base station) and 307.2 kbps in the forward direction (base station to mobile).

1xEV-DO service is considered a true 3G service since it uses many of the cdma2000 enhancements including advanced modulation and coding techniques, and the use of multiple antennas at the mobile receiver. This service uses a separate channel from the voice service, so dual mode terminals can be used for simultaneous voice and data. This service advertises a maximum theoretical transmission rate of 2.4 Mbps from the base station to the mobile station and 153.5 kbps from the mobile station to the base station. Figure 1 shows the technology migration to 3G for CDMA systems. Voice service, circuit –switched cellular, and 1xRTT are currently available on CDMA networks in most major metropolitan areas and along most major interstate and US highways. 1xEV-DO is available only in select cities in Minnesota, North Dakota, and South Dakota. However, Verizon has announced an introduction of 1xEV-DO service in Washington, DC and San Diego, California in mid-October, 2003.



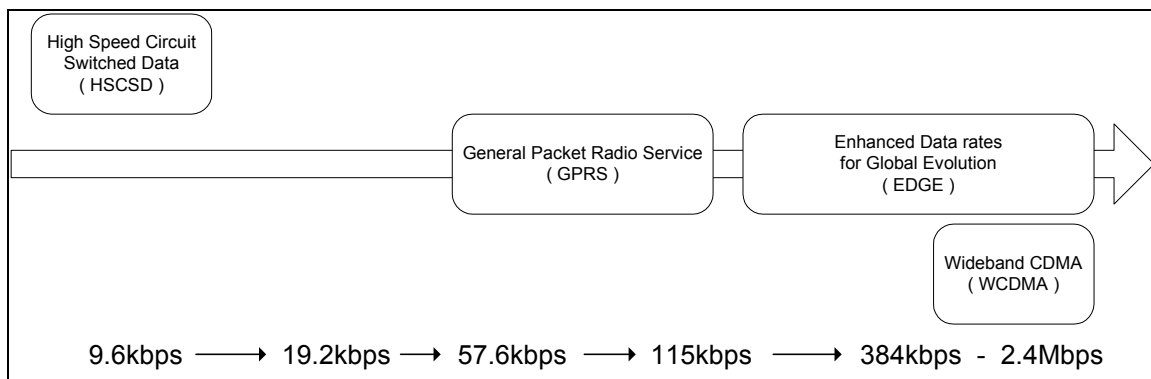
**Figure 1. CDMA Migration to 3G**

### *Global System for Mobile Communications (GSM)-Based Services*

GSM is a European-based standard that is widely implemented in many countries. It is based on a time division multiple access (TDMA) protocol that uses a 200 kHz channel. Circuit switched data is possible at either 9.6 or 14.4 kbps. There is also a short message service available that is primarily used for text messaging (maximum 160 characters per message) and paging functions on the mobile handsets.

General Packet Radio Service (GPRS) is a high speed data extension to the GSM system. There are 4 channel schemes providing data rates of 9.05 kbps to 21.4 kbps (depending on how much error protection is provided) per time slot, with up to 8 time slots per channel. Voice and data are sharing the same channels, so the data rate available will depend on how the carrier has allocated the time slots between voice and data connections, and whether there is any rate adaptation implemented.

Enhanced Data for GSM Evolution (EDGE) will use a higher order modulation (eight phase/phase shift keying) and a different set of packet structures and coding rates to achieve a theoretical maximum data rate of 513 kbps. There are also rate adaptation schemes to enable the data rate to drop if the channel conditions are poor. EDGE is not available yet in the United States, but is expected to be implemented by the GSM operators as part of their 3G migration strategy, as shown in Figure 2. Cingular announced they will be testing EDGE starting in summer 2003 in Indianapolis. Voice, GPRS, and circuit switched data services on GSM networks is available in most major metropolitan areas and along most major interstate and US highways.



**Figure 2. GSM Migration to 3G**

### *iDEN*

iDEN is a proprietary technology from Motorola used in the Nextel network. Voice calls can be made through the public switched telephone network. Also, Nextel has a feature called “Direct Connect”. This enables the phones to operate in a push to talk mode with local pre-defined talk groups. The “Push to Talk” service is a version of Direct Connect being introduced that allows the service to establish talk groups with users anywhere in the country.

Nextel offers both circuit switched data and packet switched data. The standard offering is the 9.6 kbps service. There is a packet data service with a gross data rate of 19.2 kbps, and an enhanced packet data service, called PacketStream Gold, that advertises a 56 kbps rate. The 56 kbps service is implemented by applying data compression within the Nextel network. The 56 kbps data rate is maximum effective rate that depends on how “compressible” the source data is.

### *Digital SMR*

Specialized Mobile Radio service is composed of carriers who provide two-way radio dispatch to users in public safety, construction, and transportation. SMR end users may operate in either an "interconnected" mode or a "dispatch" mode. Interconnected mode interconnects mobile radio units with the public switched telephone network (PSTN). Dispatch mode allows push-to-talk voice communications between two or more mobile units or between mobile units and fixed units on the system.

SMR systems are also being developed for data services such as two-way acknowledgment, paging, inventory tracking, credit card authorization, automatic vehicle location, fleet management, remote database access, and voicemail. The data rates are comparable to circuit switched cellular services. There are thousands of SMR operators and most systems are local or regional.

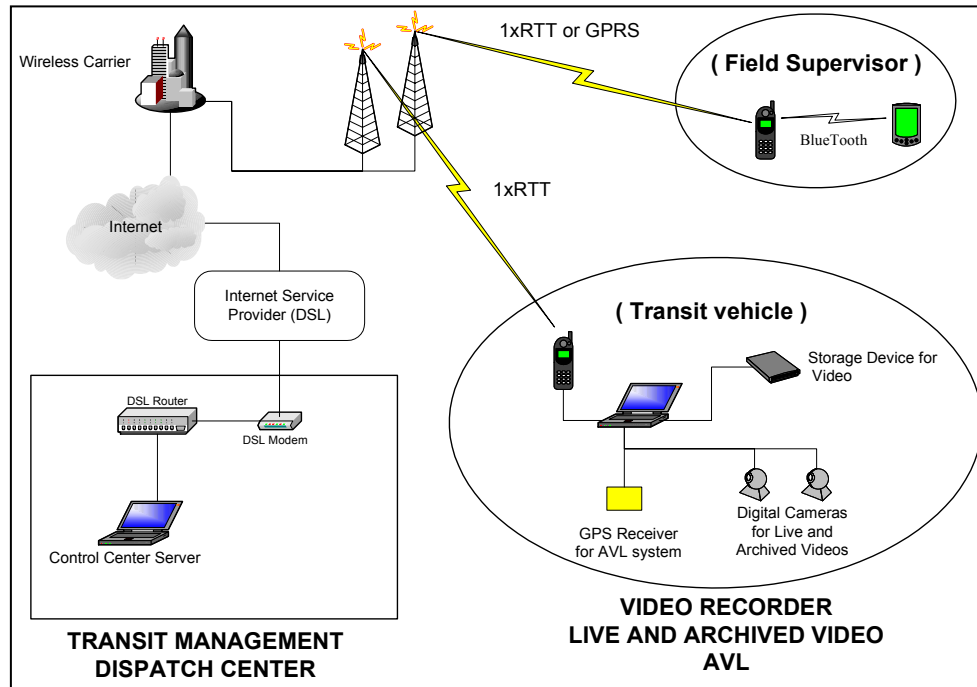
## **ISSUES FOR USE OF COMMERCIAL COMMUNICATIONS**

There are many issues that will have to be addressed in making a decision to use commercial services. Many of these issues have been thoroughly investigated in the PSWN program (see [www.pswn.gov](http://www.pswn.gov)), and the information is available on their website. The issues include:

- Availability
- Coverage
- Cost
- Security
- Product Availability
- Technology Migration
- Customer Service
- Interoperability
- Status of Legacy Systems
- Accounts and Billing
- Scalability
- Marketplace

The new emerging commercial voice and data services can provide significant increases in capability for public agencies. The high speed packet data services in particular have the potential to support new biometric identification and multimedia applications. They also are expected to have sufficient capacity to allow integration of most if not all data generating devices on vehicles, and extending mobile capabilities to supervisory personnel. However, there are several technical questions concerning coverage, availability, and useable data rates that need to be addressed through comprehensive testing.

Mitretek is performing laboratory testing of GPRS and 1xRTT services and has developed a prototype of a digital video recorder function to provide real time security for transit vehicles. Mitretek is also testing some applications for use by field personnel. Figure 3 shows the prototype being used.



**Figure 3. Prototype Test Configuration**

There are several important issues that have arisen in discussions with public agencies that have seen a demonstration of the prototype. These are carrier provisioning, dispatch services, and how systems using wireless technology are manufactured for public agencies.

*The first issue, carrier provisioning, pertains to the actual data rates available to the subscriber compared to the maximum data rate described in a standard.* Carriers still receive most of their revenue from voice services, and data services such as GPRS and 1xRTT share a channel with voice. The data rate made available to subscribers is, in part, an economic decision by the carrier in terms of how much voice capacity they should give up to provide data services for these types of protocols. In our early testing, we discovered, and had one provider verify, that the equivalent of only one of the eight available voice channels on the upstream and four on the downstream were being made available for GPRS. Application level data rate testing showed throughputs on the order of 10 kbps on the uplink for GPRS, which was insufficient to support our video application from the vehicle to the dispatch center. The downlink had an application level rate of between 35 and 45 kbps (depending on the provider) which was sufficient to enable us to forward video frames to police for viewing on a PDA while they are en-route responding to the incident. Average 1xRTT uplink data rates were around 25 kbps for

weak signal conditions and 35 kbps for strong signal conditions. This allowed us to support video at several frames per second from the vehicle to the operations center.

Mitretek has been testing the data throughput capabilities of these services in the laboratory. Table 2 shows a sample of the throughput for the GPRS service from ATT Wireless and T-Mobile in Falls Church, Virginia. This table represents the actual amount of user data being transferred; the transmission rate is higher to account for overhead associated with wireless packet data transmission. The data in the table consists of the average data rate observed (in kbps) over a ten minute transmission period every hour, 24 hours each day for two weeks. The downlink rate for this service is three to four times higher than the uplink (between 30 to 40 kbps), since it is optimized for Internet access. Mitretek is doing additional testing with other GPRS carriers and plans to perform testing in a mobile environment in the near future.

Modem Used	Uplink	Downlink	Measurement Date
Ericsson T68m (T-Mobile)	9 kbps	31 kbps	May – June, 2003
MERLIN G100 (T-Mobile)	9 kbps	32 kbps	March – April, 2003
Ericsson T68i (AT&T)	9 kbps	41 kbps	June, 2003
Theoretical Max Rate	172 kbps	172 kbps	

**Table 2. Sample Average GPRS Throughput**

Table 3 shows a sample of 1xRTT throughput rates in kbps for Verizon Wireless in Falls Church, Virginia. The throughput rate of this service varies with available signal strength and channel loading. It exhibits considerably more variation than GPRS does, but averages consistently higher than GPRS at this specific location. Similar to GPRS provisioning, the downlink rates are significantly higher (between 75 and 80 kbps). These rates, like the GPRS rates are user data rates with overhead (such as error correction, header information, etc.) not included. These results are preliminary and additional testing is in progress.

Modem Used	Uplink	Downlink	Measurement Date
Kyocera 2235 (Weak Signal)	30 kbps	81 kbps	February – March, 2003
Kyocera 2235 (Strong Signal)	37 kbps	74 kbps	May – June, 2003
AirCard 555 (Weak Signal)	8 kbps	42 kbps	March – April, 2003
AirCard 555 (Strong Signal)	10 kbps	54 kbps	May – June, 2003
Theoretical Max Rate	144 kbps	307 kbps	

**Table 3. Sample Average 1XRTT Throughput**

*The second issue is the lack of dispatch-style communications for voice.* Currently, Nextel and Verizon are the carriers that provide communications to talk groups through a “push-to-talk” style service. Sprint has announced plans to introduce a “push-to-talk” service by the end of this year, so with multiple carriers offering this service, this may cease to be an issue.

***The third issue and probably most important one we discussed with public agencies pertained to the design of the systems they procure that use wireless transmission.***

Public agencies are accustomed to installing systems that will be in operation for ten or more years. Wireless communications, when used to support devices like PDAs and laptops can be upgraded easily and quickly by swapping out a wireless card and loading new software. Manufacturers of AVL systems and other systems that collect data are being manufactured with wireless modems embedded into the system. These modems were not designed to be replaced, and upgrading, if it is even feasible, will likely have to be done by the manufacturer at a cost that is unknown. Agencies that employ systems using CDPD are currently facing this issue and are scrambling to try to figure out whether the system can be upgraded, and if so, what service to replace CDPD with. Some agencies are expecting their CDPD service to be phased out within 18 months, and have very little time to make a decision. The choice of a new service may not be a simple one. CDPD was a service based on static IP addressing. The emerging replacement services use dynamic IP addressing (some carriers will offer static addresses for an additional fee) and have changed their routing protocols. These features may not be compatible with the existing CDPD applications.

Services like 1xRTT and GPRS are interim technologies in the implementation of 3G networks. For example, 1xRTT has been available in the Washington DC area for less than a year, and one vendor has announced the introduction of the next phase of the CDMA2000 service, 1xEV-DO in several cities in October, 2003. There is also considerable activity by the carriers to integrate hot-spot coverage with wide area cellular service. Hot spots are locations, such as airports, coffee shops and civic centers where high speed wireless internet access has been installed using the WiFi™ standard. The introduction of new wireless communications protocols and enhanced features are coming more rapidly than ever before. Public sector agencies that plan to use commercial services need to procure systems using wireless communications that allow for simplified modem upgrading or replacement. Otherwise, there is the risk that the system will become either obsolete or at worst, inoperable for lack of communications support long before it needs to be replaced.

## REFERENCES

Airvana Inc., “All-IP 1xEV-DO Wireless Data Networks”, Airvana White Paper, 2001

Bettstetter, Christian, Eberspacher, Jorg, Vogel, Hans, “GSM Phase 2+ GPRS: Architecture, Protocols and Air Interfaces”, IEEE Communications Surveys, Vol. 2, No. 3, 1999

Cai, Jian, Goodman, David, “General Packet Radio Service in GSM”, IEEE Communications Magazine, October, 1997

CDMA Development Group, “CDMA Technology: A Comparison Between GPRS and cdmaOne Packet Data”, [www.cdg.org/tech/gpros.asp](http://www.cdg.org/tech/gpros.asp)

CDMA Development Group, “EDGE: Introduction of High Speed Data in GSM/GPRS Networks”, [www.cdg.org/tech](http://www.cdg.org/tech)

Harte, Hoenig, McLaughlin, Kta, “CDMA IS-95 for Cellular and PCS”, McGraw Hill, 1999

Kain, Carl, “FCC Actions Concerning Analog Cellular Radio in the Biennial Review”, Mitretek Systems ITS Public Safety Issues Paper 01-02, 20 October, 2001

Kain, Carl, “Capital Region Integrated Wireless Network for Incident Management (CAPWIN) Commercial Wireless Data Technology Survey”, Mitretek Systems, 5 September 2000

Kain, Carl, “Spectrum Management Issues for the FTA”, Mitretek Systems, 1 December, 1998

Nextel Website, [www.Nextelonline.Nextel.com](http://www.Nextelonline.Nextel.com)

Ojanpera, Tero, Prasad, Ramjec, “An Overview of CDMA Evolution Toward Wideband CDMA”, IEEE Communications Surveys, Vol. 1, No. 1, 1998

Scourias, John, “Overview of the GSM”, University of Waterloo, October 1997

Transit Cooperative Research Program, “Impact of Radio Frequency Refarming on Transit Communications”, TCRP Report 11, Transportation Research Board, 1996